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MASTER OF SCIENCE IN FOOD AND NUTRITION

Fermentation of Yam (*Dioscorea batatas Decne*) by Lactic Acid Bacteria and Sensory Evaluation of the Fermented Yam Mixed with Plant Juice Concentrates

유산균을 이용한 산약 발효 및 식물 주스 농축액을 첨가한 발효 산약의 관능품질 평가

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Abstract

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Yam (Dioscorea Batatas Decne) contains high contents of starch. In the present work, a dry yam tuber extract was hydrolyzed by α-amylase, pullulanase, and malt enzyme extract and fermented with lactic acid bacteria (LAB) to develop a fermented Yam beverage retaining the health benefits of a probiotic culture. The starter culture strain was selected by comparing the viable cell counts of the various LAB during the fermentation of the enzyme treated yam extracts

(ETYE). *L. bulgaricus* showed a high growth rate in ETYE media and was therefore chosen as the fermenting microorganism. The sensory value of the fermented yam beverage was optimized by response surface methodology (RSM). Eighteen formulations of beverage with different ingredients were prepared: jujube extract (1−10%), blueberry extract (1−10%), mango juice (1−10%) and a group of 30 panelists responded to the sensory evaluation. The formulation optimizing both sweetness and sourness was composed of 6.53% of jujube, 7.41% of blueberry, and 10% of mango.

Keywords

Yam, lactic acid bacteria, fermented beverage, sensory acceptance, response surface methodology (RSM).

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Contents

Abstract i

Contents iii

List of Figures v

List of Tables vii

List of Abbreviations viii

MATERIALS AND METHODS 3

Materials 3

2.1. Preparation of yam extract (YE) media 4

2.2. Analysis of sugars produced during enzymatic hydrolysis 5

2.3. Chemical analyses 6

2.4. Microbiological analysis of the fermented ETYE 7

2.5. Optimization of fermented yam beverage by response surface methodology (RSM) 8

2.6. Sensory evaluation 9

RESULTS AND DISCUSSION 10

3.1. Analysis of sugars produced during enzymatic hydrolysis by TLC 10

3.2. Fermentation of yam with various LAB 12

3.3. pH, titrated acid and contents of sugar during fermentation with *Lactobacillus. bulgaricus* KCTC 3188. 15

3.4. Optimization of fermented yam beverage composition 20

CONCLUSION 33

REFERENCE 34

Abstract in Korean 38

List of Figures

Figure 1. TLC profile of the sugars of enzymatically hydrolyzed yam (ETYE) and non- enzyme treated yam (control group). 11

Figure 2A. Changes of the pH during fermentation of ETYE by *Lactobacillus. bulgaricus* KCTC 3188.....16

Figure 2B. Changes of the titrable acidity (TA) during fermentation of ETYE by *Lactobacillus. bulgaricus* KCTC 3188.....17

Figure 2C. Changes of the reducing sugars during fermentation of ETYE by Lactobacillus. bulgaricus KCTC 3188.....18

Figure 2D. Changes of the Viable cell counts (log CFU/mL) during fermentation of ETYE by *Lactobacillus. bulgaricus* KCTC 3188.....19

Figure 3. Response surface for the effect of blueberry and jujube on sweetness of fermented yam beverage (Design-expert plot).....26

Figure 4. Response surface for the effect of jujube, blueberry, and mango juice on sourness of fermented yam beverage (Design-expert plot). 28

Figure 5. Response surface for the effect of jujube, blueberry, and mango juice on mouth feel of fermented yam beverage (Design-expert plot). 30

Figure 6. Response surface for the effect of jujube, blueberry, and mango juice on overall acceptance of fermented yam beverage (Design-expert plot).....32

List of Tables

Table. 1. Microbial counts during YE and ETYE fermentation. 13

Table. 2. Sensory characteristics of LAB fermented yam extract at vario us conditions by Central Composite Design (CCD). 23

Table. 3. Statistical analysis of sensory evaluations and predicted model equation for optimization of sensory acceptance of the fermented yam extract. 25

List of Abbreviations

YE: Yam extract

ETYE: Enzyme treated yam extract

LAB: Lactic acid bacteria

TLC: Thin-layer chromatography

RSM: Response surface methodology

INTRODUCTION

Tropical roots and tubers such as sweet potato, cassava, and yams serve as important staple foods all around the world (1). These food crops are stable food in West Africa and are now frequently cultivated throughout most parts of tropical South America, Africa, Australia, India and South-East Asia (2). They are major sources of energy for hundreds of millions of impoverished people in developing countries which suffer from rapid population growth and high urbanization rate (3). However, low productivity, limited added value, and poor access to markets due to the perishable nature of these products, are major constraints that are still insufficiently addressed.

On the other hand, in oriental regions like Korea, China, and Japan both rhizomes and aerial tubers of yam are used in traditional medicine for the treatment of some metabolic abnormalities including hyperglycemia (4), arteriosclerosis (5), obesity (6), lipid metabolism (7), gut dysfunction (8,9) or for the improvement of blood circulation (10) and prevention of colon carcinogenesis (11). Roots and tuber crops of the yam were introduced in the Pharmacopoeia of the People's Republic of China for their use in the treatment of anorexia, chronic diarrhea, diabetes, seminal emissions, and excessive leucorrhea (12). In addition, Dioscorea rhizomes have shown positive effects on immune systems (13). The Dioscorin protein extracted from yam tubers possesses an anti-oxidative activity (14). Moreover, yam contains dioscin, a

steroid saponins, and diosgenin, a steroid sapongenin, which are widely used for industrial production of steroidal drugs (15). Yam contains over 70% of starch, mainly composed of amylose and amylopectin (16). It also contains mucilage which holds various components like amino acids (aspartic acid, glutamic acid, leucine, glycine, etc.) (17), and carbohydrates (mannose, arabinose, glucose, xylose, and rhamnose) (18). Yam provides good carbon and nitrogen sources (19). They can stimulate bacteria's growth when added to the media and therefore be used for the production of value-added fermented food.

The addition of different probiotic microorganisms into edible products increase their health potential and can therefore be a good commercial value as nowadays people are more aware of how their diet influences on the maintenance of their health. The Chinese yam extract was found to increase the amount of lactose-fermenting bacteria in the intestine of rats (12). This result suggests Chinese yam extract enhances the conversion of some intestinal flora to helpful bacteria. Taken together, a process using LAB to ferment yam could be used to design products possessing promising market potential.

In this study, the primary objective is the development of the fermented yam using LAB. The second objective is the optimization of the sensory attributes of the product.

MATERIALS AND METHODS

Materials

All chemicals were purchased from Sigma Aldrich (Sigma, St. Louis, MO, USA). The chemicals used in this study were of analytical grade. Bifidobacteria and Lactobacilli strains, isolated from the feces of adults and infants, were obtained from the Food Microbiology Laboratory Strain Collection at the Seoul National University, Korea. Amylase (from *B. licheniformis,* 15,500 U/mL) was purchased from Sigma Aldrich (Sigma, St. Louis, MO, USA). Pullulanase (from *B. licheniformis*, 600 U/g) was purchased from Bision Co. Ltd (Seongnam-si, Gyeonggi-do, Korea). Centrifugation was carried out using eppendorf centrifuge VS-15000N, Vision Scientific, Daejeon, Korea. Man Rogosa Sharp (MRS) medium was purshased from Difco, Detroit, MI, USA. Malt was purchased from local market, milled and mixed with sterile deionized water in a 1:5(w/v) ratio. The mixture was heated while shaking at 50° C for 40 min. Then the filtered solution was as uesd as malt enzyme extract.

2.1. Preparation of yam extract (YE) media

Dried yam tubers were purchased from the market. They were peeled and cut into uniform 1 cm thick slices and then milled. The yam flour was stored at −20° C until use. The yam flour was mixed with sterile deionized water at a 1:10(w/v) ratio and heated at 95° C for 4 h in a water bath. After cooling, the yam extracts were reacted with a combination of α−amylase, pullulanase and malt extract at 0.1% (v/v) ratio each and then the solution was incubated at 55° C. The hydrolysis degree was analyzed during incubation (0 time, 10 min, and 1 h) after boiling the samples in a water bath for 5 min to stop the reaction. Subsequently the enzyme treated yam extract was adjusted to pH 6.5 using 1 M $NaHCO_3$ and used to grow various experimental bacteria.

2.2. Analysis of sugars produced during enzymatic hydrolysis

The composition analysis of the sugars produced during enzymatic hydrolysis was performed by thin layer chromatography(TLC) using a 20×20 cm silica gel 60 F254 (Merck KGaA, Darmstadt, Germany). *n*-Butanol, ethyl acetate and deionized water were mixed at a ratio of (4:1:5(v/v/v)) to compose the mobile phase. The released free sugars were identified by comparing to the standard sugars such as glucose and maltose. Samples and butanol were mixed at a ratio of 1:1(v/v), and then centrifuged at 10000 ×*g* for 10 min. Then,10 μL of the supernatant was spotted and developed on the TLC plate. The results were visualized by staining the TLC plates upon spraying 10% sulfate dissolved in ethanol and heating them in an oven at 110° C for 10 min.

2.3. Chemical analyses

pH and titratable acidity (TA) of the samples were measured at room temperature. The pH was directly measured using a pH meter, and the TA was titrated with 0.1 N NaOH using a 0.5% phenolphthalein indicator to an end point of pH 8.2 (20). The formula used for calculating the percentage of lactic acid is as follows:

Lactic acid (%)

= [0.1 N NaOH used (mL) × 0.009 × 100]/sample (mL)

The reduced sugar concentration was determined by the 3, 5-dinitrosalicylic acid (DNS) method using glucose equivalents (21).

2.4. Microbiological analysis of the fermented ETYE

Bifidobacteria and LAB were stored at −70° C in 30%(v/v) sterile glycerol. They were activated by two successive pre−cultures in MRS medium containing 0.05%(w/v) cysteine−HCl (Sigma, St. Louis, MO, USA) at 37° C for 18 h. The ETYE was autoclaved at 121° C for 15 min and then inoculated with activated bacteria (1% (v/v)).The samples were incubated at 37° C under anaerobic conditions. During the fermentation process, viable cell counts were assessed at different times 0, 24, 48, and 72 h. For that, 100 μL of each sample was added to 0.9 mL of PBS buffer and then diluted to 10^{-7} and plated in triplicate before being incubated at 37° C for 48 h in anaerobic conditions. Man Rogosa Sharp (MRS) plate count agar (Difco Laboratories, Detroit, MI) was used for LAB counting and BL plate count agar was used for bifidobacteria counting. The viable cell counts of the bifidobacteria and LAB strains grown in ETYE were compared with respect to the growth patterns in order to screen for the most efficient bacteria strain.

2.5. Optimization of fermented yam beverage by response surface methodology (RSM)

The software Design-Expert version 8.0.6 (Stat-Ease Corporation, USA) was used for the experimental design and for RSM analysis. Analysis of variance (ANOVA) was used to verify significant differences among means ($p < 0.05$). A 2^3 Central Composite Design (CCD) with six axial points and four central points, in total 18 formulas, was used to determine the optimum concentration of jujube extract, blueberry extract, and mango juice (independent variables) in the fermented yam beverage. The experiments were carried out at random in order to minimize the effect of unexplained variability in the responses due to systematic errors (15). The variation range was based on the results obtained in a preliminary experiment. The behavior of the response surface was investigated for response function (Y) using the polynomial regression equation (a). The equation for generalized RSM is given below.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \varepsilon \quad (a)$$

Where Y is the predicted response; X1 and X2 are the levels of independent variables, respectively, $\beta 0$ is the intercept term; β_1, β_2 and β_3 are the linear coefficients; β_{12}, β_{13} and β_{23} are the interactive coefficients; β_{11}, β_{22}, and β_{33} are quadratic coefficients; and ε is the random error.

2.6. Sensory evaluation

Thirty panelists, all of whom are graduate students from the Food and Nutrition Department of Seoul National University in Korea, performed the sensory evaluation. The ages of the panelists ranged from 20 to 35 years old. They were allocated in 3 different groups and six samples were provided to each group. The samples were presented in a monadic sequential order, arranged by the RSM with Design Expert program. The samples were supplied in 100 mL paper cups coded with three digit random numbers and kept at room temperature before being tasted. Panelists were instructed to taste samples in order from left to right and score each sample independently for its sweetness, sourness, mouth feel, and overall acceptance. The sensory attribution of the fermented yam beverage was evaluated according to a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) (22, 23). Unsalted soda, crackers and room temperature water were provided with palate cleansers to be used before and between each sample-tasting. After completing the sensory evaluation, panelists were asked to answer demographic questions including age and gender.

RESULTS AND DISCUSSION

3.1. Analysis of sugars produced during enzymatic hydrolysis by TLC

The combination of amylase, pullulanase, malt extract were used for the hydrolysis of the YE as described in Material and Methods. TLC analysis of the enzymatically hydrolyzed YE is shown in Figure 1. The controls after 10 min and 1 h incubation showed very faint bands of low molecular weight sugars such as glucose and maltose. As expected, the ETYE showed distinct bands of glucose, maltose, and maltotriose even after 10 min and no further increase thereafter. It was reported that yam tuber being rich in starch and mucilage, can be an important sugar source upon hydrolyzation of the polysaccharide. Therefore, the appropriate concentration of the ETYE may result in a highly nutritious environment enhancing the growth of LAB (22). Amylase and amylopectin are the two major components of the yam starch. Amylose, the minor component, consists mainly of alpha−(1, 4) linked D− glucopyranosyl residues. However, amylopectin is composed of linear chains of α−1, 4−D−glucose residues connected through α−1, 6−linkage (5−6%). Amylose and amylopectin contents of native yam starch were 30 and 70% (27). The enzyme treatment of the YE yielded efficient production of the low molecular weight sugars from Yam starch, which is expected to improve the growth environment for the lactic acid bacteria.

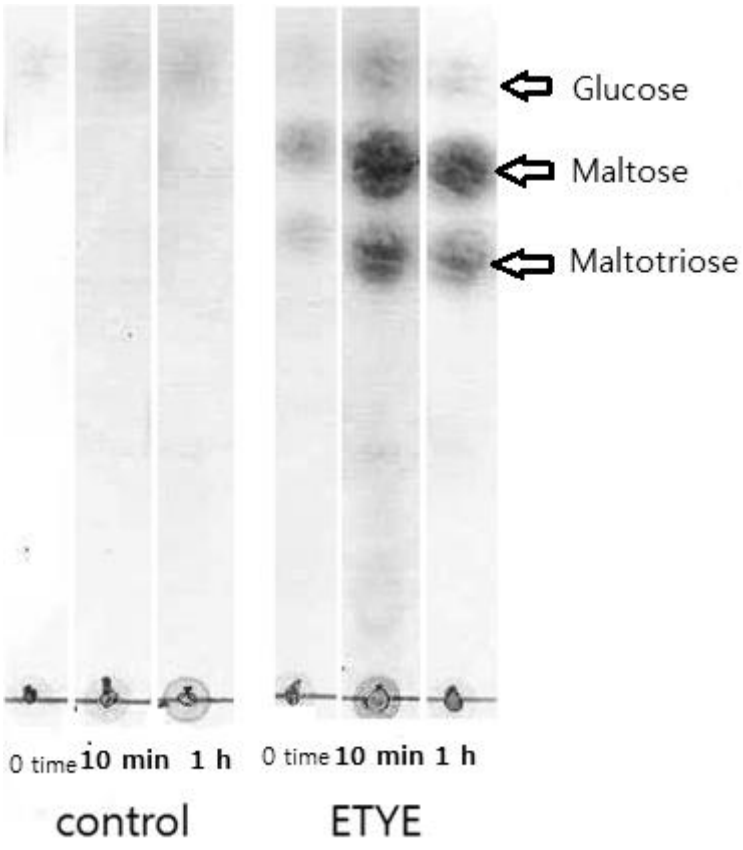


Fig.1. TLC profile of the sugars of enzymatically hydrolyzed yam (ETYE) and non- enzyme treated yam (control group).

3.2. Fermentation of yam with various LAB

Previous studies have shown that media containing 6% of YE lacked for the supply of nutrients for the active growth of LAB. Therefore, in the present study a 10% YE containing media was used. Furthermore, the effect of YE and ETYE were compared. Table 1 shows the result of LAB counting when they are incubated in YE or in ETYE for different lengths of fermentation time. All ETYE treated samples showed higher numbers of LAB during the fermentation than those of the non-enzyme treated controls (Table 1). This result indicates that the enzyme treatment leads to the increase in the rate of the bacteria cell growth during the fermentation process. *L. bulgaricus* KCTC 3188 showed much better growth when incubated in ETYE than in YE, and showed excellent growth upon 24 h incubation. More specifically, this study incited us to choose *L. bulgaricus* KCTC 3188 as the fermenting microorganism used for further design of the product.

Table. 1. Microbial counts during YE and ETYE fermentation.

		Viable cell count (log CFU/mL)			
LAB strain	Time	0 h	24 h	48 h	72 h
Bifidobacterium longum subsp. *infantis* ATCC 15697	ETYE	7.3	8.7	8.7	8.9
	YE	7.8	8.5	8.7	8.3
L. plantarum KFRI 348	ETYE	7.3	8.6	9	8.7
	YE	7.3	8.4	8.5	8.1
Bifidobacterium sp. SJ32	ETYE	6.6	6.5	7.2	<5
	YE	6.8	5.7	0	<5
B. longum BORI	ETYE	6.9	6.5	6.7	<5
	YE	7.3	7.6	<5	<5
Bifidobacterium sp. Int57	ETYE	7.9	7.2	8.2	7.9
	YE	7.3	6.3	6.5	5.7
B. adolescentis INT57	ETYE	6.9	7.7	8.4	6.8
	YE	7.1	7	7.2	7.1
B. breve ATCC 15700	ETYE	5.7	6.3	8.5	8
	YE	6.3	6.3	8.1	7.2

Leuconostoc mesenteroides subsp. *mesenteroides* KFRI 00690	ETYE	7.4	8.5	7.4	<5
	YE	7.4	8.3	8.8	7.4
Lactococcus lactis subsp. *lactis* KCTC 2013	ETYE	6.9	7.2	6	<5
	YE	7.4	7.4	7.3	7.3
L. bulgaricus KCTC 3188	ETYE	7.8	9	8.6	8.8
	YE	7.7	7.9	8.1	8.4
B. bifidum BGN4	ETYE	6.8	7.9	7.2	8.8
	YE	7	6.6	7.1	5.3
B. longum ATCC 15707	ETYE	6.2	8.9	8.7	8.2
	YE	7.5	8.3	8.8	8.7
L. acidophilus KCTC 3154	ETYE	7.3	8.2	8.5	8.6
	YE	7.7	8	8.7	8.6

3.3. pH, titrated acid and contents of sugar during fermentation with *Lactobacillus. bulgaricus* KCTC 3188.

As the results shown on Fig.2A. The pH of the ETYE without fermentation was 4.92. After adjusting the pH to 6.5 and autoclaving, the pH of ETYE was initially 4.67, which is similar to the original sample, indicating that the yam extract did not have a very high buffering capacity. After undergoing fermentation for 24 h, the pH of the ETYE sample decreased to 4.05. Subsequently, the pH decreased further over a fermentation period of 48 h and remained stable thereafter until the end of fermentation at 72 h. As the results shown on Fig.2B. TA increased as fermentation proceeded from 0 to 48 h. After fermentation for 48 h, the total amount of acid was equivalent to 0.52 g/100mL of lactic acid. The TA increase was correlated with pH decrease and may be attributed to the hydrolysis of the carbohydrate and subsequent conversion of the sugars to acid by the *Lactobacillus. bulgaricus* KCTC 3188.

Sugar content of the fermented ETYE was shown on Fig. 2C. The concentrations of reducing sugars gradually decreased during fermentation for 48 h from an initial value of 3.49 to 1.40 mg/100mL.

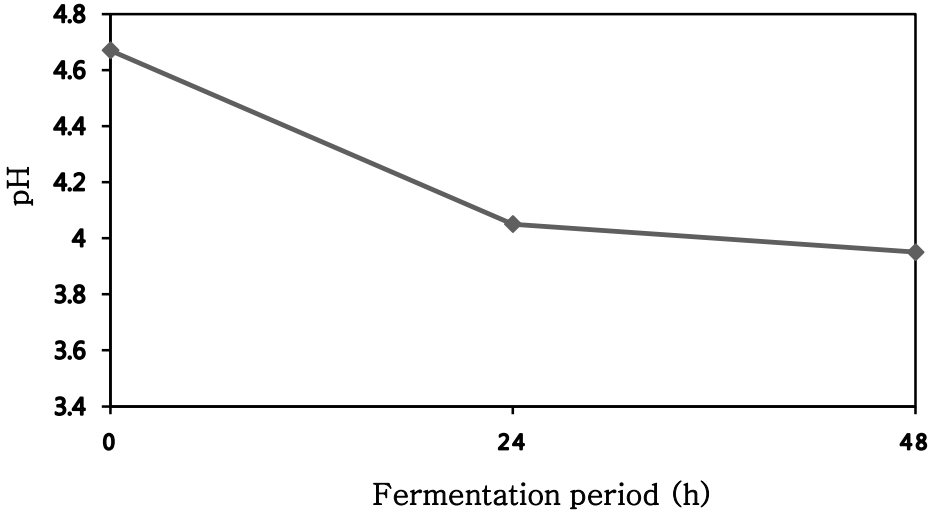


Fig.2A. Changes of the pH during fermentation of ETYE by *L. bulgaricus* KCTC 3188.

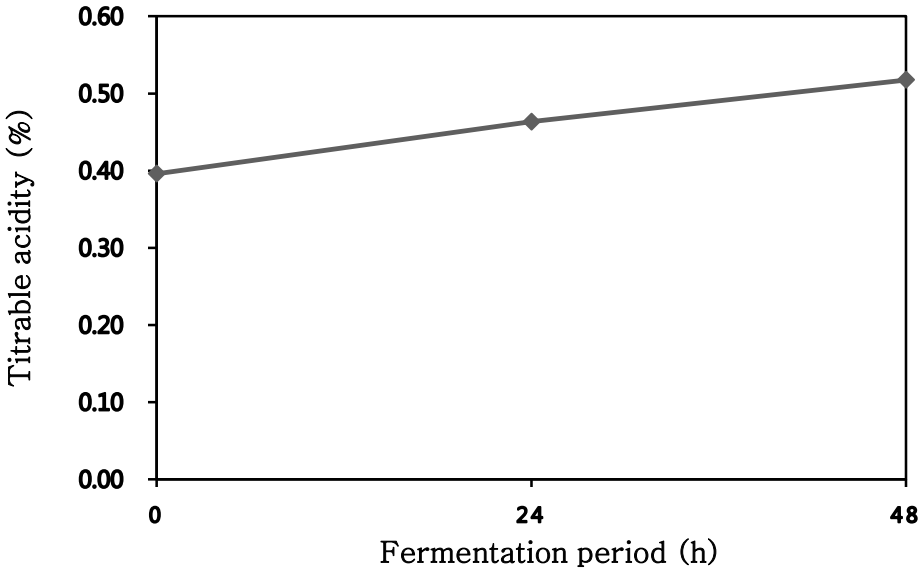


Fig.2B. Changes of the titrable acidity (TA) during fermentation of ET YE by *L. bulgaricus* KCTC 3188.

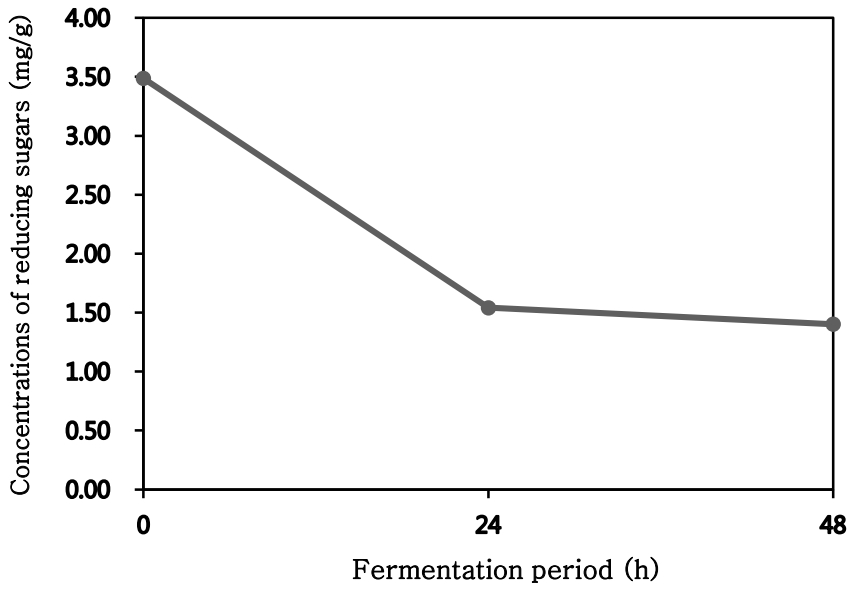


Fig. 2C. Changes of the concentrations of reducing sugars during fermentation of ETYE by *L. bulgaricus* KCTC 3188.

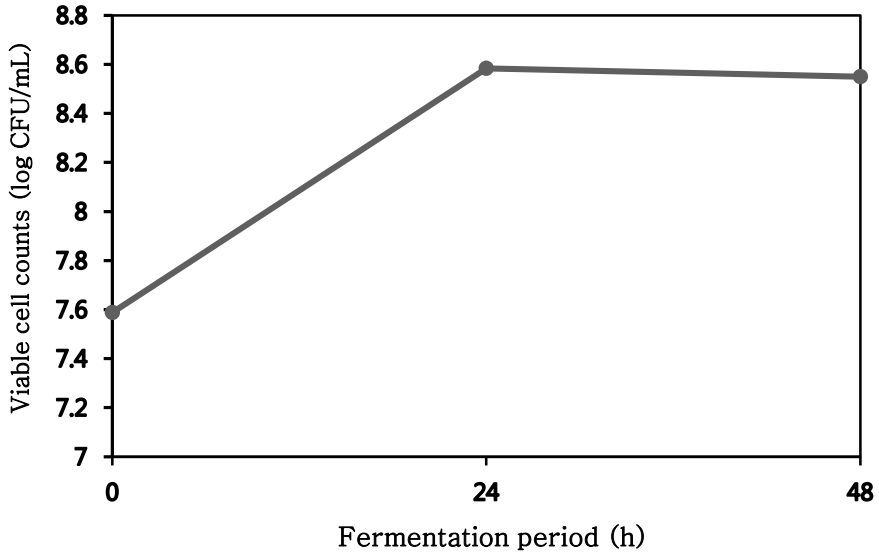


Fig.2D. Changes of the viable cell counts (log CFU/mL) during fermentation of ETYE by *L. bulgaricus* KCTC 3188.

3.4. Optimization of fermented yam beverage composition

Through a preliminary evaluation, jujube extract, blueberry extract and mango juice were selected amongst 27 different ingredients, to improve the sensory properties of the yam beverage fermented by *L. bulgaricus* KCTC 3188. These ingredients seem to possess interesting properties. Jujube has the ability to improve the sweetness of the product, whereas mango has been frequently used to improve the smell of the various food products. The yam is easily discolored. The browning may result in undesirable sensory to people, consequently decreasing the commercial value of the yam product which can be avoided by using blueberry extract as a coloring agent.

RSM was used to study the effects of adding jujube extract (variable X_1), blueberry extract (variable X_2), and mango juice (variable X_3) on the sensory attributes of the fermented beverage.

The results of a consumer acceptance test usually shows a wide range of individual differences in sensory preferences. Therefore, in order to examine the overall sensory acceptance of the fermented ETYE, the 4 sensory qualities: sweetness, sourness, mouth feel and overall acceptance were assessed (24). The influence of each ingredient’ s ratio on the sensory characteristics is shown in Table 2.

Through the consumers sensory analysis the results of the 4 sensory qualities were as follows: the scores of sweetness ranged from 4.7 to 6.2, the

scores of sourness ranged from 4.6 to 6.3 and the scores of mouth feel ranged from 4.1 to 5.7. The sensory analysis are subsequently used to design the predicted model equations which are used to optimize the composition of the beverage. ANOVA analysis was conducted in order to determine the significance of the quadratic model. The *p*-values were used as a tool to check the significance of the models and indicate the presence of co-effects between the ingredients on the sensory acceptance of the beverage.

The second-order polynomial equations of the sensory acceptance are presented in Table 3. All the predicted model equations are significant ($p \leq 0.05$).

p-Value less than 0.0001 indicates that jujube highly influences the sweetness whereas blueberry's influence is not that significant and mango has no effect at all. Mango juice did not show any interaction with the two other variables in the results of sensory acceptance of sweetness, however, X_1X_2 variable had a significant *p*-value (0.01) indicating that jujube and blueberry co-effected the sensory analysis of sweetness. X_1^2 variable had a significant *p*-value (0.01) indicating that the sensory acceptance was not a linear response of the variables.

The *p*-values of the sourness was mainly influenced by the blueberry and jujube extract. Mango juice's influence was found to be less significant. X_1X_2 variable had a significant *p*-value (0.04) indicating that jujube and blueberry had a co-effect on the sensory analysis of sourness (in which mango has no interaction with jujube or blueberry). Also as shown above, X_1^2 variable had a significant *p*-value (0.01) indicating that the sensory acceptance was not a

linear response of the variable.

Considering the *p*-values of the mouth feel acceptance was mainly influenced by the jujube extract. The blueberry extract and mango juice's influence was found to be not significant. X_1X_2 variable had a significant *p*-value (0.03) indicating that jujube and blueberry and also blueberry and mango juice have co-effects on the sensory analysis of mouth feel acceptance. Also, X_2^2 variable had a significant *p*-values (0.04) indicating that the sensory acceptance was not a linear response of the variables.

Considering the *p*-values of the overall acceptance was mainly influenced by the jujube extract and then by blueberry extract. Mango juice's influence was found to be not significant X_1X_2 and X_2X_3 variable had a significant *p*-values (0.02 and 0.38 respectively) indicating jujube and blueberry and also blueberry and mango juice have co-effects on the sensory analysis of overall acceptance. Also as shown above X_1^2 variable had a significant *p*-value (0.04) indicating the sensory acceptance was not a linear response the variables.

According to the three-dimensional response surfaces (Fig.3.4.5.6.), when the concentration of jujube extract and blueberry is increased, the scores of sensory acceptance increase. However, when the concentration of jujube and blueberry extract are high enough for the sensory acceptance to be over the saddle point, the acceptance score decreases. This observation suggests that the optimal conditions determined for the sensory acceptance of sourness are: jujube extract at 5.5%, mango juice at 5.5%, and blueberry extract around 1%.

Table. 2. Sensory characteristics of LAB fermented yam extract at various conditions by Central Composite Design (CCD).

No.	Variable level[1)]			Response (sensory characteristics)[2)]			
	X_1	X_2	X_3	Sweetness	Sourness	Mouth feel	Overall acceptance
1	5.5	5.5	5.5	6.21±1.64	6.29±1.36	5.04±1.63	5.42±1.45
2	10	10	10	5.37±1.52	5.82±1.87	5.00±1.64	5.37±1.94
3	5.5	5.5	5.5	5.63±1.26	4.83±2.20	4.87±2.13	4.85±1.86
4	1	1	10	5.53±2.33	5.39±2.36	4.93±1.99	4.99±2.26
5	1	10	10	5.72±1.07	5.89±2.26	5.17±1.71	5.64±1.79
6	5.5	5.5	5.5	5.22±1.74	5.80±1.84	4.98±2.07	4.75±2.30
7	5.5	1	5.5	5.64±1.84	5.30±1.72	4.68±2.15	5.91±2.06
8	5.5	5.5	1	5.89±1.51	5.53±1.94	4.18±2.30	5.68±1.15
9	1	10	1	5.25±1.17	5.22±1.59	5.09±1.65	5.35±1.26
10	10	1	1	5.08±1.77	4.60±2.32	4.13±1.54	4.33±2.40
11	5.5	5.5	10	5.21±2.08	4.88±2.02	4.43±2.45	4.73±2.48
12	10	10	1	6.18±1.32	6.06±1.14	5.68±1.47	5.93±1.39

13	1	1	1	5.36±2.14	4.78±1.83	4.98±2.41	4.73±2.52
14	5.5	10	5.5	5.45±1.49	5.18±2.25	4.58±2.55	4.77±1.62
15	1	5.5	5.5	6.04±1.41	5.59±1.65	4.29±1.13	4.52±1.30
16	10	5.5	5.5	5.24±2.20	4.85±2.19	5.08±2.59	4.73±2.53
17	10	1	10	4.73±2.45	5.27±1.88	4.38±2.26	4.41±2.85
18	5.5	5.5	5.5	5.36±1.24	5.43±1.83	5.10±1.45	5.39±1.69

[1] X_1: Jujube extract (%); X_2: Blueberry extract (%); X_3: Mango juice (%)

[2] Mean±SD.

Table. 3. Statistical analysis of sensory evaluations and predicted model equation for optimization of sensory acceptance of the fermented yam extract.

Sensory characteristics	Model	F-value	Prob > F	Lack of fit	Predicted model equation
Sweetness	Quadratic	11.66	< 0.0001	0.28	$Y=6.08+0.58X_1+0.4X_2-0.39X_1X_2-0.39X_1^2-0.42X_2^2$
Sourness	Quadratic	4.81	< 0.0001	0.23	$Y=5.84+0.38X_1+0.55X_2+0.31X_3-0.36X_1X_2-9.375E-003X_1X_3-0.028X_2X_3-0.78X_1^2-0.46X_2^2+0.4X_3^2$
Mouth feel	Quadratic	5.31	< 0.0001	0.47	$Y=5.20+0.71X_1+0.2X_2+0.12X_3-0.34X_1X_2+0.075X_1X_3-0.28X_2X_3-0.39X_1^2-0.55X_2^2+0.23X_3^2$
Overall acceptance	Quadratic	7.92	< 0.0001	0.04	$Y=5.56+0.91X_1+0.53X_2+0.18X_3-0.39X_1X_2-0.088X_1X_3-0.15X_2X_3-0.60X_1^2-0.094X_2^2-0.18X_3^2$

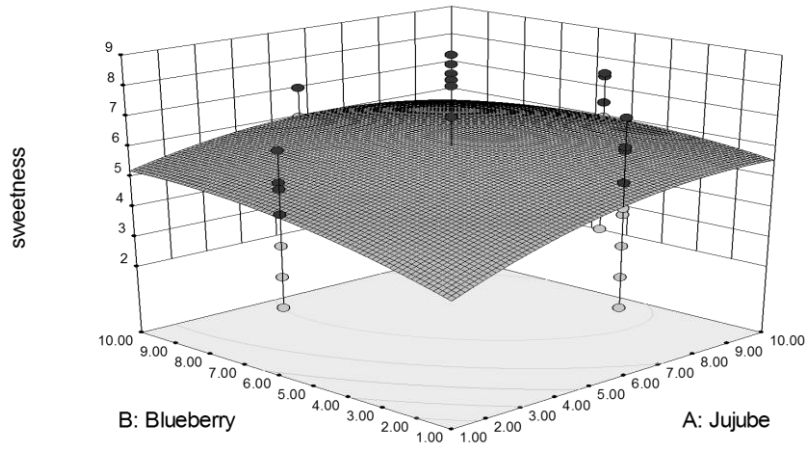
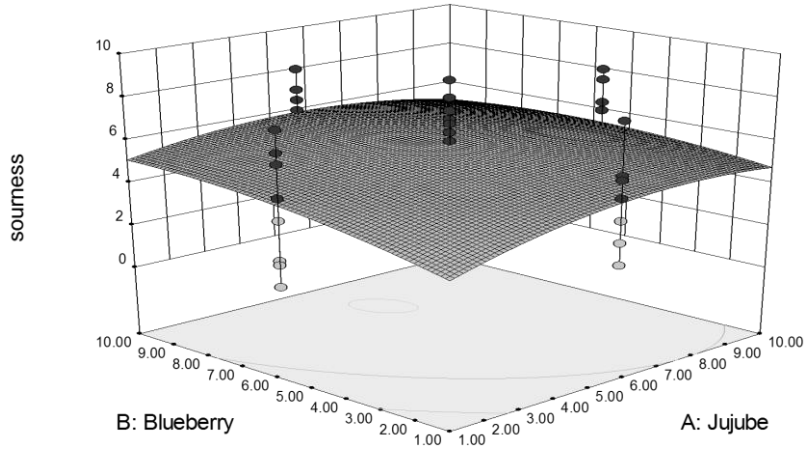
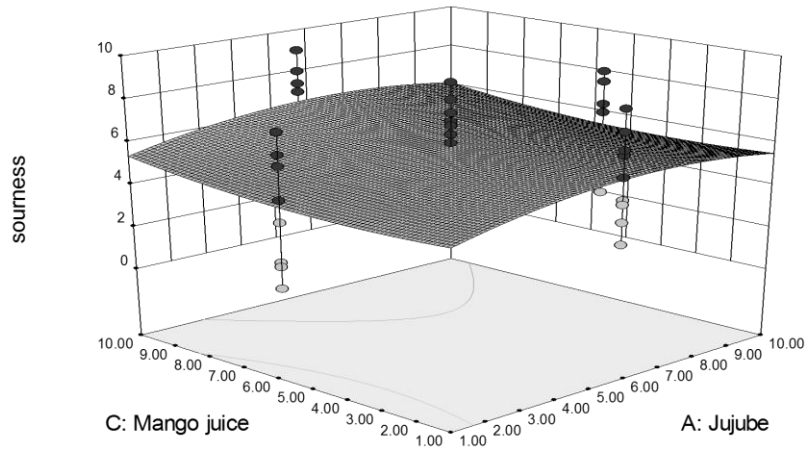


Fig.3. Response surface for the effect of blueberry and jujube on sweet ness of fermented yam beverage (Design-expert plot).

A


sourness
10
8
6
4
2
0
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
B: Blueberry
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
A: Jujube

B


sourness
10
8
6
4
2
0
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
C: Mango juice
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
A: Jujube

C

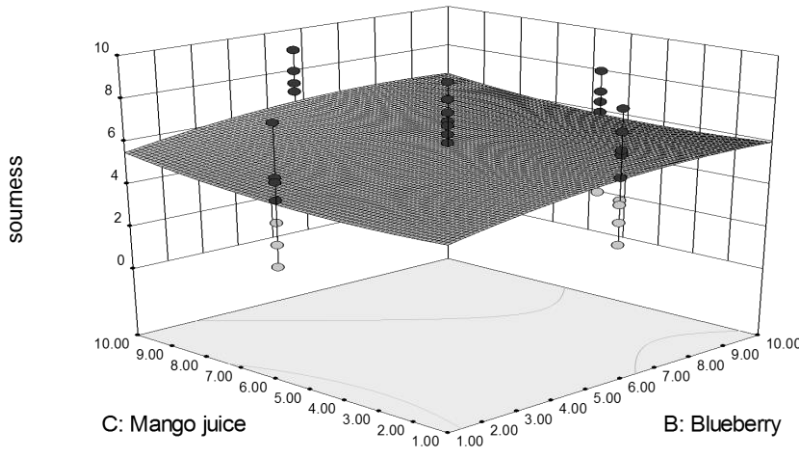
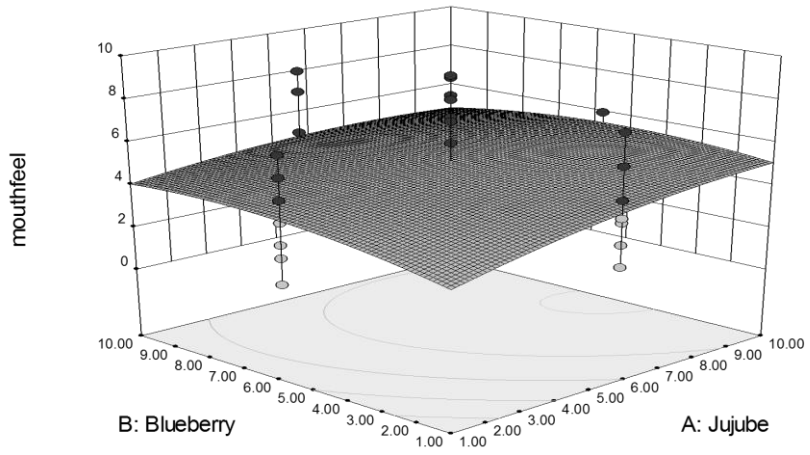
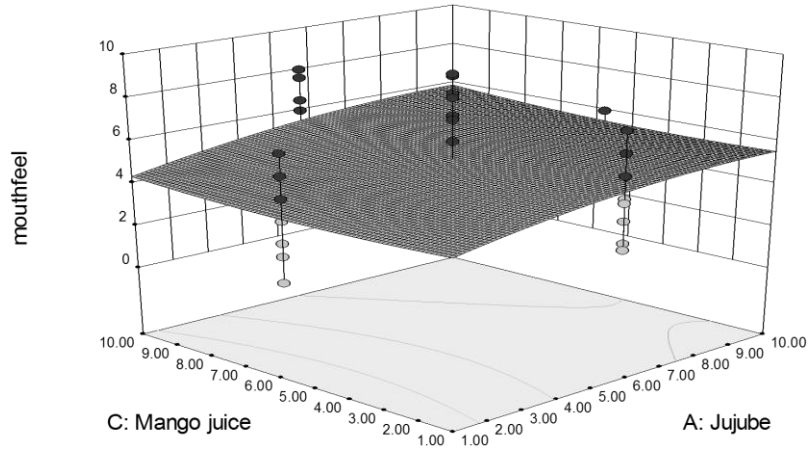


Fig.4. Response surface for the effect of jujube, blueberry, and mango juice on sourness of fermented yam beverage (Design-expert plot).

A.


mouthfeel
10
8
6
4
2
0
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
B: Blueberry
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
A: Jujube

B


mouthfeel
10
8
6
4
2
0
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
C: Mango juice
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
A: Jujube

C

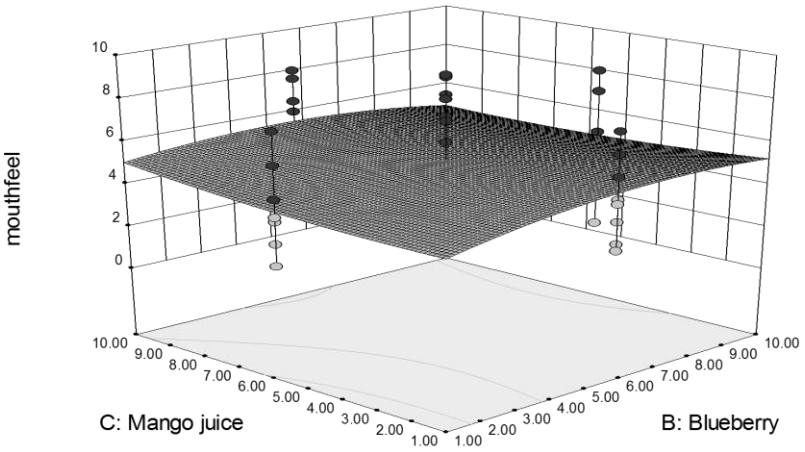
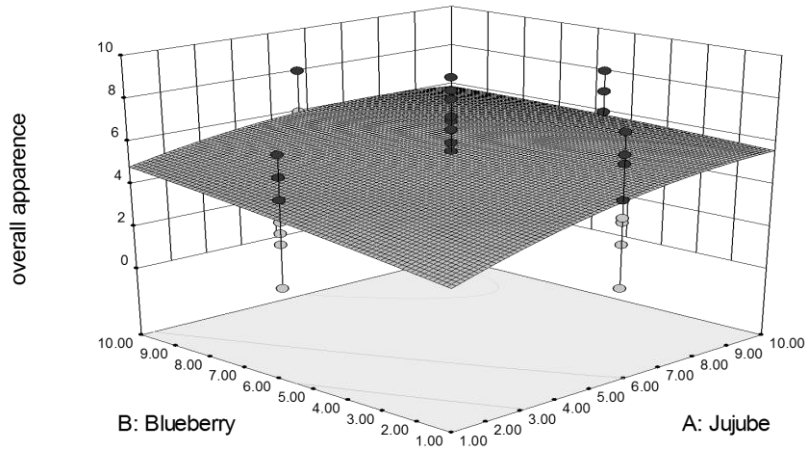
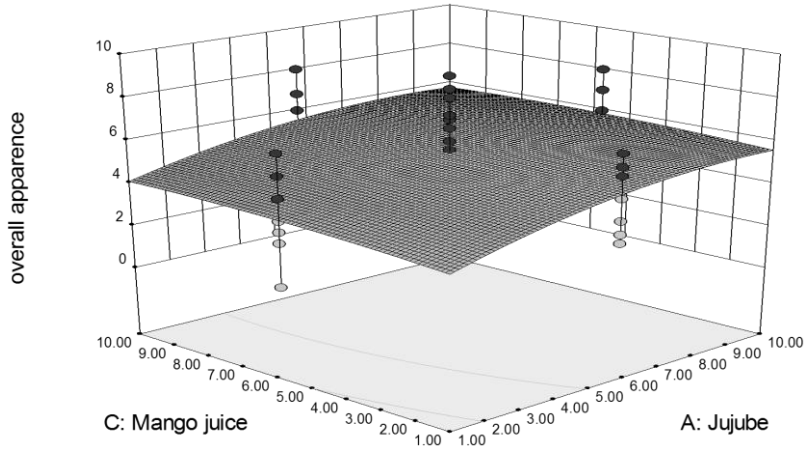


Figure.5. Response surface for the effect of jujube, blueberry, and mango juice on mouth feel of fermented yam beverage (Design-expert plot).

A


overall apparence
10
8
6
4
2
0
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
B: Blueberry
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
A: Jujube

B


overall apparence
10
8
6
4
2
0
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
C: Mango juice
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
A: Jujube

C

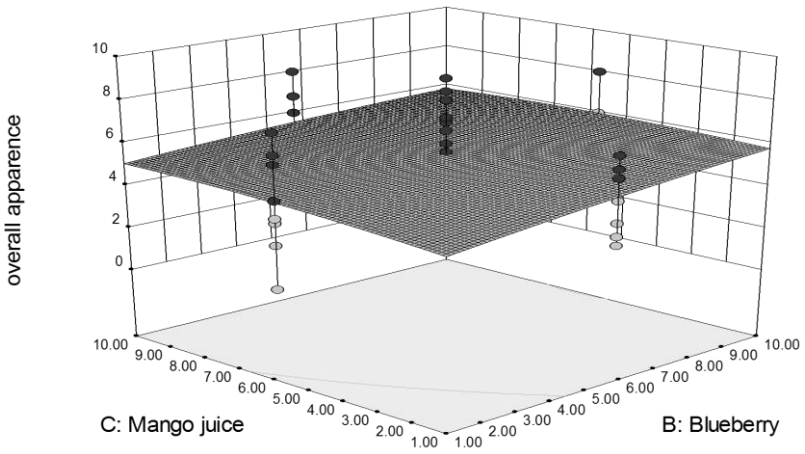


Figure.6. Response surface for the effect of jujube, blueberry, and mango juice on overall acceptance of fermented yam beverage (Design-expert plot).

CONCLUSION

The present study was designed to find a functional probiotic beverage of yam based product. Through the study on several factors affecting the fermentation efficiency, the present study established the enzyme treatment for the hydrolysis of yam extract, and optimization of the sensory value of the fermented yam. The predictive models adjusted for the variables of jujube extract, blueberry extract, and mango juice showed good predictive capacity. And could be used for the production of the consumer-friendly fermented yam beverage.

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Abstract in Korean

산약(Dioscorea Batatas Decne)은 한국에서는 ‘마’로 불리며, 마 속 식물은 주로 열대 또는 아열대 지역에 야생한다. 특히 한국, 중국, 일본 등 나라에서 전통적인 식품소재 내지 의약소재로 쓰고 있다. 그러나 마를 이용한 발효 식품 또는 발효 음료제품은 많이 연구되어 있지 않다. 본 연구는 다양한 생리활성기능을 지니고 있는 마를 이용하여 기호 성을 높인 발효 음료를 제조하기 위한 기초연구로 산업화하기 위하여 프로바이오틱스를 이용하여 산약을 발효시킨 유산발효음료의 제조공정을 개발하였다. 산약의 주성분은 전분, 점액 성 다 당질 등이며, 발효 미생물의 성장을 촉진시키기 위해서 amylase, pullulase, 그리고 맥아로부터 추출된 효소 액을 이용하여 당화과정을 진행하였다. 이에 따라 *Lactobacillus*속 및 *Bifidobacterium* 속 균주를 선별하여 최종적으로 *L.bulgaricus* KCTC 3188를 발효 균주로 선정하였다. 또한, *L.bulgaricus* KCTC 3188를 이용한 산약 발효 음료의 관능적 품질특성을 높이기 위하여 반응표면분석법을 이용하여 소비자 기호도 조사를 통해서 최적적 식물 주스 농축액의 배합 비를 탐색하였다. 즉, 산약 발효 음료의 단맛과 신맛을 최대화하였을 때 대추농축액의 첨가량은 6.53%, 블루베리농축액의 첨가량은 7.41%, 그리고 망고 주스의 첨가량은 10% 이었다. 본 연구를 통하여 마 발표에 적합한 유산균을 선발하였고 식물 주스 농축액 배합을 통하여 발효마의 관능품질을 개선시켰다.

주요어: 산약, 젖산균, 발효음료, 관능품질 평가, 반응표면분석법

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